California State Polytechnic University, Pomona

ME 5741 – Biomechanical Robots

Project #3: Design and Fabrication of a Jumping Robot

Project Report

CAL POLY POMONA

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Introduction

The design that was proposed and built for Project #3 is a jumping robot that uses a "parallel elastic leg mechanism" as a "mechanical escapement" to convert stored energy into kinetic energy that is released at a single instant [1]. This is how the Salto team at UC Berkeley described the type of jumping mechanism being proposed. The robot developed by the Salto team uses saltatorial locomotion inspired by grasshoppers and bushbabies. Saltatorial locomotion is described as locomotion that is achieved by the chaining of jumps. The design built in this project achieves locomotion via storing energy into a torsion spring like that created in the paper titled "A miniature 7g jumping robot" from EPFL in Switzerland and showcased in Figure 1 [2].

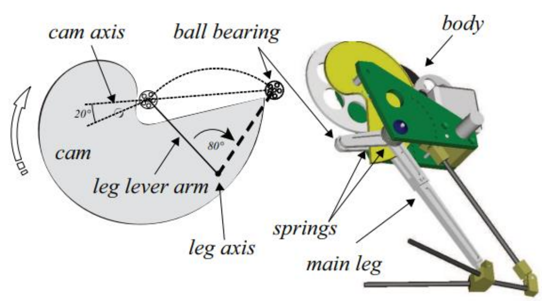


Figure 1. 7g Jumping mechanism prototype capable of heights up to 1.4 m

The minimum requirements of the jumping robot proposed and built in this design were that it shall achieve a jump height of at least one body height and shall land two jumps consecutively. Unfortunately, the final version of the robot was not able to complete the requirement of landing two jumps consecutively. The robot, however, was successful in achieving a jump height of approximately 5 inches compared to a total body height of 4.5 inches. There were several issues encountered that led to an unsuccessful robot. First, the lack of availability of strong, lightweight, and small materials for the frame and joints led to a bulky and heavy final robot. Second, the torsion springs that were sourced did not produce enough explosive force for the robot to jump a very large height with all components mounted, such as the IMU, battery, boost converter, and microcontroller. Therefore, it was decided to keep all components separate from the robot and run wires to its motor and IMU, which are considered critical components for function. The issue with this setup is that the wires would bias the motion of the robot's jump to the direction of the wiring.

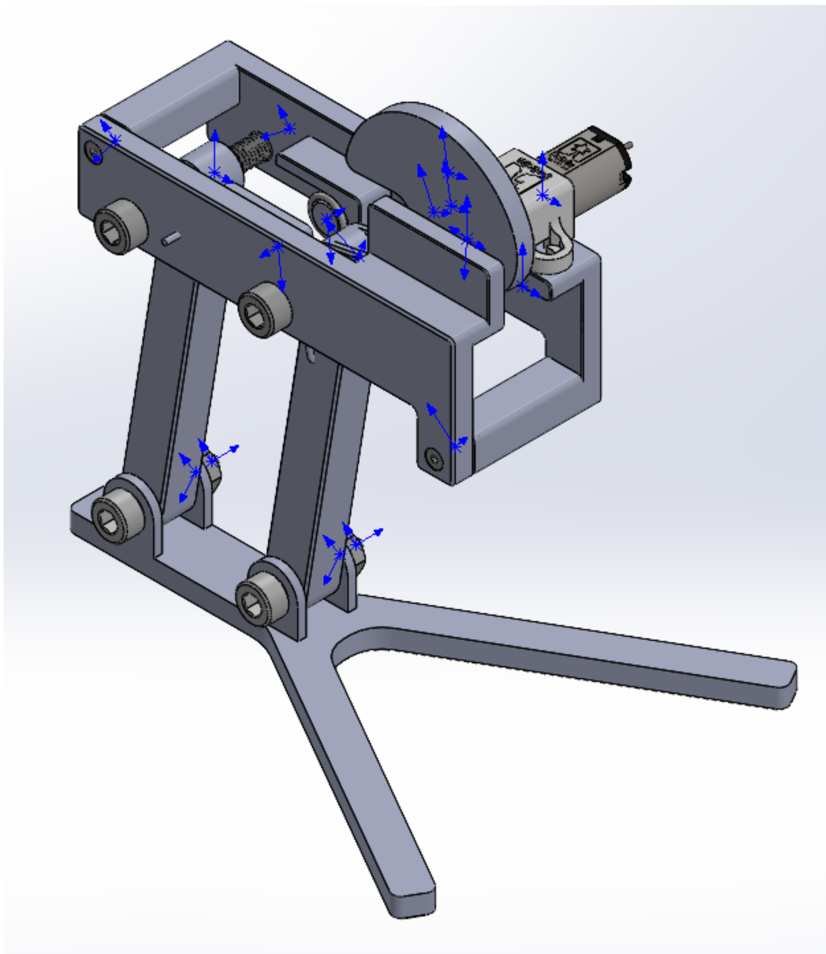
Design/Fabrication

Several iterations were designed and tested using a mix of 3D printed parts and of the shelf components. The propulsion method of the final design used two 2.879 in.-lbs. springs charged by a motor with a 1:1000 gearbox with a stall torque of approximately 9.5in.-lbs. The motor had sufficient power to charge the springs but due to the voltage required by the motor, an external power supply was needed to power it. Additionally, a 6-DOF IMU was used to track the acceleration and rotation of the robot mid-jump. Extremely low-density 3D printing methods were implemented to keep weight as low as possible. 5% infill settings with a .2mm layer height were used. Additionally, to keep the components as rigid as possible, each part was printed with 4 perimeter layers. Some webbing designs were simulated and tested, but their effect on weight was mostly negligible thanks to the low infill density. Furthermore, to keep the weight of the robot as low as possible, processing and power were not mounted on the robot. Instead, wires were attached to the robot from an external source. This in turn caused issues during jumping by biasing the robot in one direction, causing landing to be extremely difficult and unpredictable.

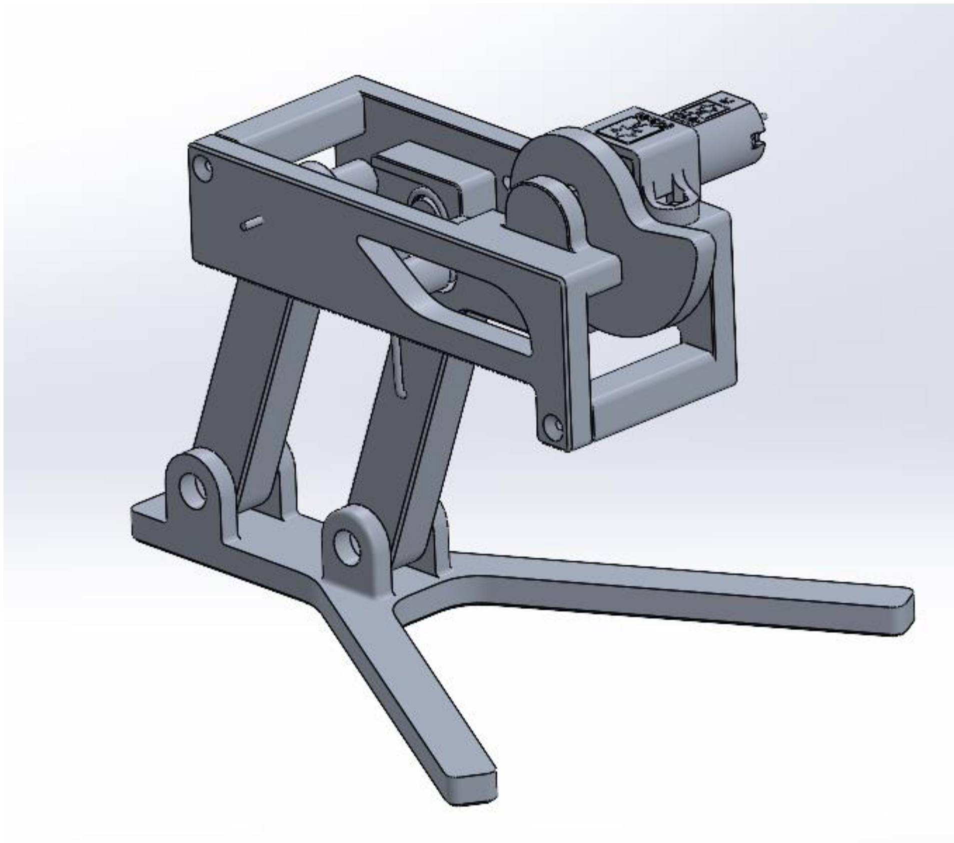
Conclusion/Future Work

In future revisions, utilizing thin but strong frames and joints made of aluminum sheet metal would greatly improve the robot's capabilities. In addition to a stronger frame, stronger springs could be used to offset the weight of incorporating all electronic components onto the frame. By making the robot wireless, the robot would have improved stability and no longer stray towards the side the wires are attached to. Additionally, the development of a proper flywheel or reaction wheel to stabilize the robot mid-flight is deemed necessary for consistent propulsion and landing. Incorporating a mechanism to dampen the landing force without affecting propulsion would also contribute to the robot's ability to jump twice. Another method of jumping should also be considered since the method used in this paper inherently causes the robot to flip due to the rotation of the upper body during propulsion. A method that transmits the spring's energy in a nearly pure vertical trajectory could result in less complications due to the robot rotating in-flight. Overall, this project demonstrated the many challenges faced with developing a robot, specifically the need for a perfect balance between weight and performance.

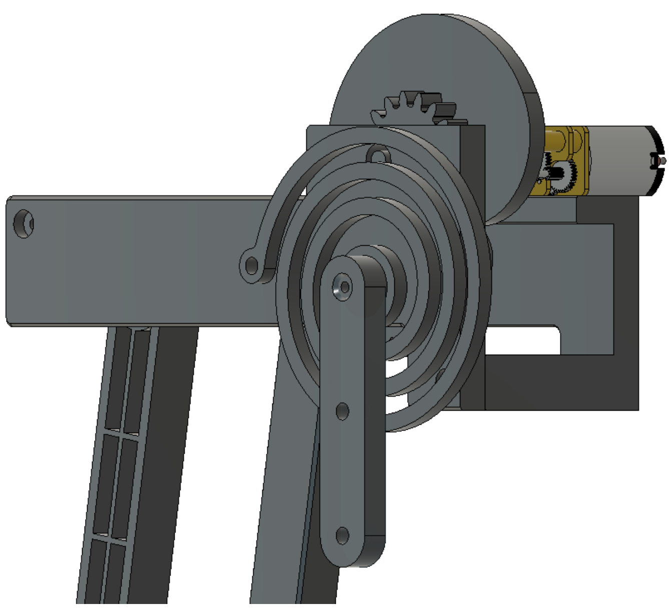
Appendix



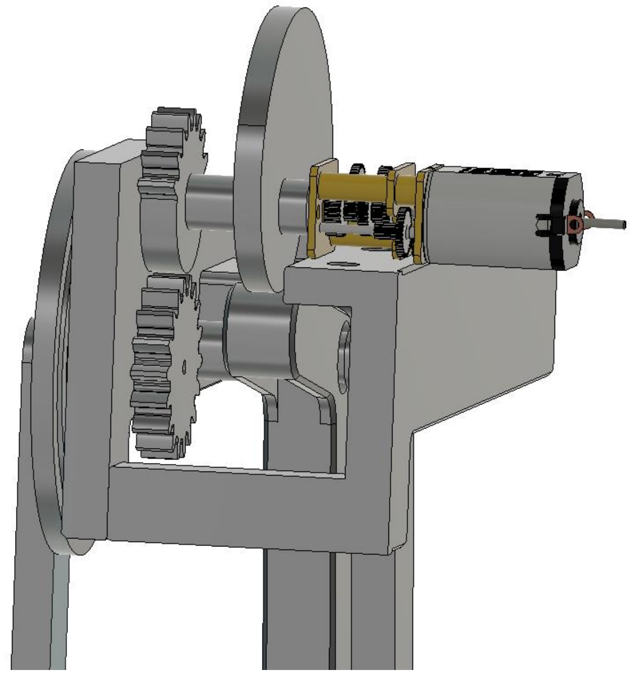
Revision 4



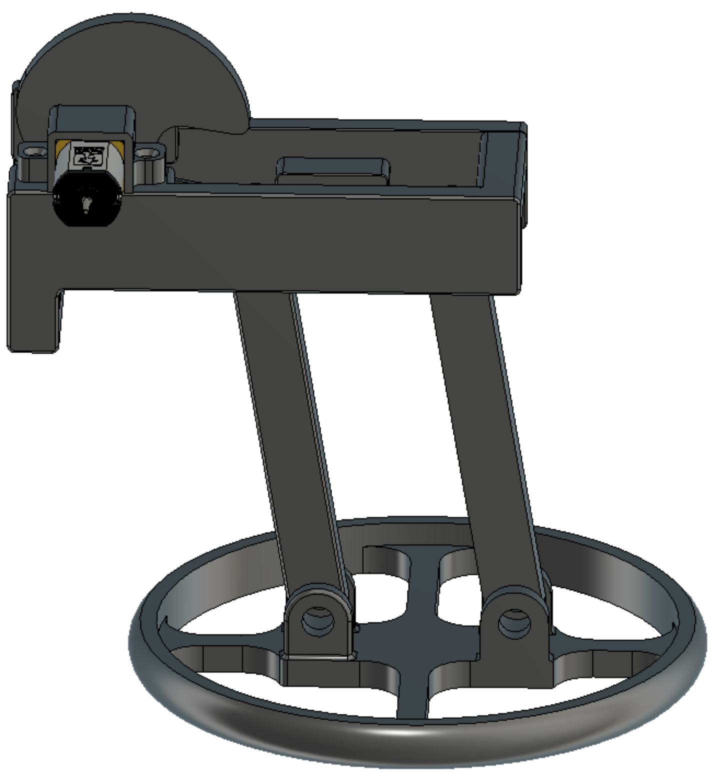
Revision 5



Flywheel with 3D printed torsion spring

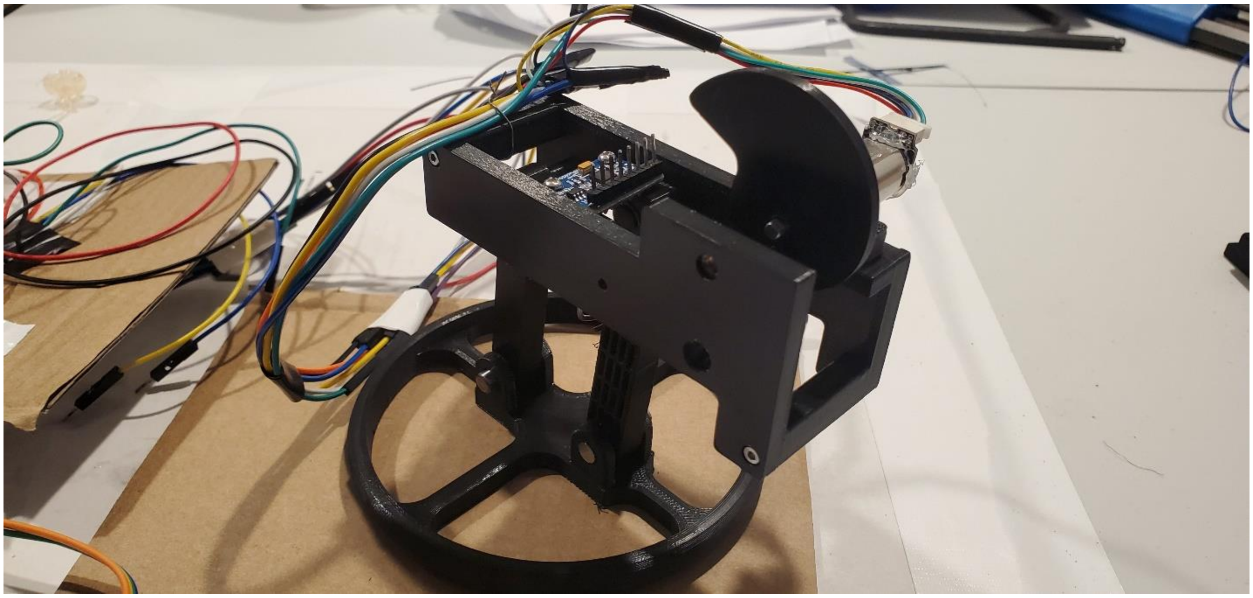


Flywheel with 3D printed torsion spring showing gears in phase with cam

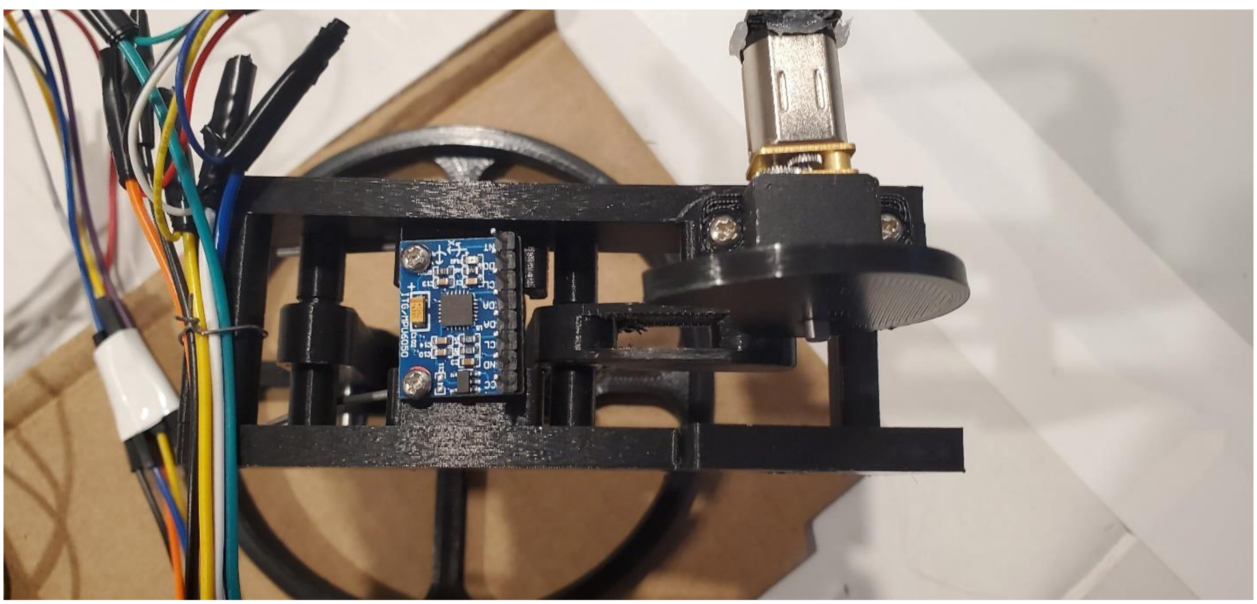


Final Revision – Revision 6

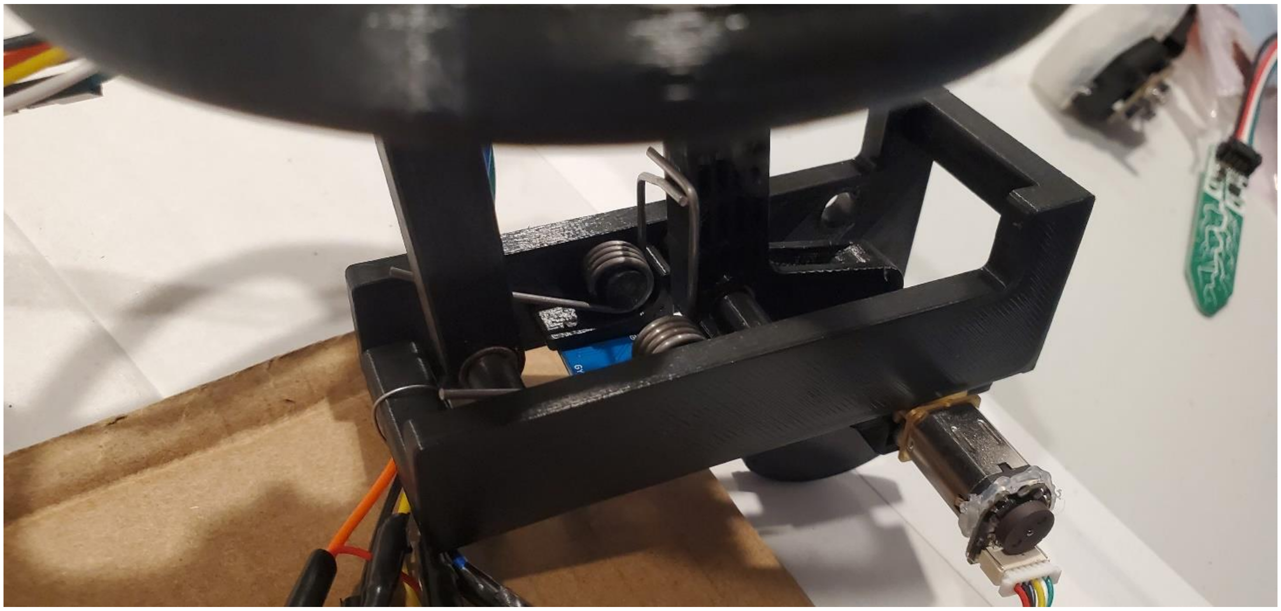
Various Images of the final robot construction



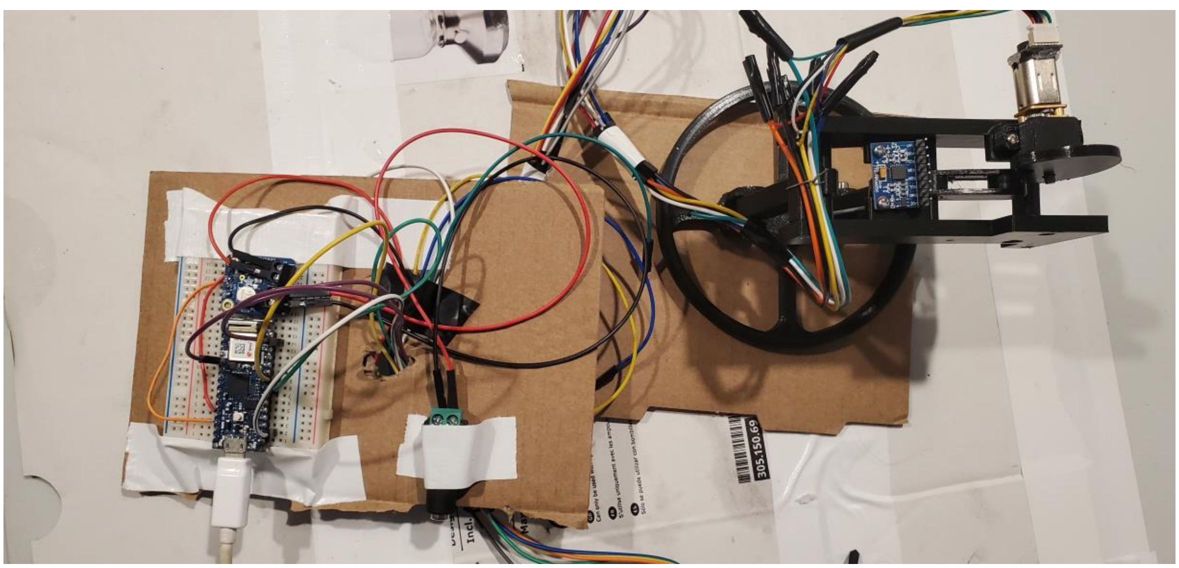
Isometric view



Top view showing accelerometer and internals



Underside view showing spring placement



Microcontroller and Motor Driver board on “wiring harness”

Deconstructed image showing spring placement and bronze oil-embedded bearings

Static stress analysis of a solid leg segment versus a webbed leg segment with .8mm (.031”) webbing.
30N of force was applied to the center of the leg

Gyroscope and accelerometer data from IMU during a single jump – Unfortunately these values did not seem accurate